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# THD assessment of cascade H-bridge multi-level inverter

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## ABSTRACT

***The conventional inverters have the drawbacks of Harmonics as well as Total Harmonic Distortion (THD). The assessment of THD and harmonics are studied in this paper by using MATLAB simulation. The cascaded H-bridge multi-level inverter configuration is used. The used configurations contain less number of switches and produce lesser harmonics in the output voltage. The harmonics and THD at the output of cascaded H-bridge inverter of different levels i.e. five-level, seven-level, nine-level, eleven-level and thirteen level are studied and compared. The cascaded H-bridge multi-level inverter topology quashes the THD and harmonics and they are very popular in power conversion systems for high power and power quality demanding applications.***

**Keywords:** *Cascade h –bridge multilevel inverter, D.C Voltage source, MOSFETs, Harmonics, THD.*

## 1. INTRODUCTION

The consumption of electricity is growing day by day. Due to a deficiency in fossil fuels and problems in the environment caused by traditional power generation, renewable energy becomes very popular and demanding. The search for a stable, reliable and efficient power has always been the main concern in energy conversion from renewable resources. This has encouraged researchers to design more efficient conversion systems. Among energy conversion systems, Multilevel Inverters (MLI) have shown several advantages and benefits such as reduced stress on switches, lower change in voltage with respect to time at inverter output voltage higher efficiency and less harmonic distortion. To connect the renewable energy sources with the electricity grid there should be matching in voltage and frequency with the help of inverters. To achieve this multilevel inverter is employed. A multi-level inverter achieves high power ratings.

## 2. MULTI-LEVEL INVERTER

A multi-level inverter is an electronically operated device. Which synthesize the AC voltage from several different levels of DC voltages. Each additional DC voltage level adds a step to the AC voltage waveform.

Abundant MLI configurations have been matured and few are proposed during the last few years. Basically, multilevel inverters can be classified into three types described below.

• Diode Clamped MLI

• Flying Capacitor MLI

• Cascade H-Bridge MLI

### 2.1 Diode Clamped MLI

Firstly, it was projected by "Akagi, Takashi, and Nabae in 1981 and also known as neutral point converter. Diode-clamped or neutral point inverters require a large number of diodes. Clamping diodes are used by the diode clamped multi-level inverters to bound voltage stress of the devices. A m level inverter requires 2(m-1) switching devices,(m-1) input voltage source and(m-1)*(m-2) operating diodes.

 

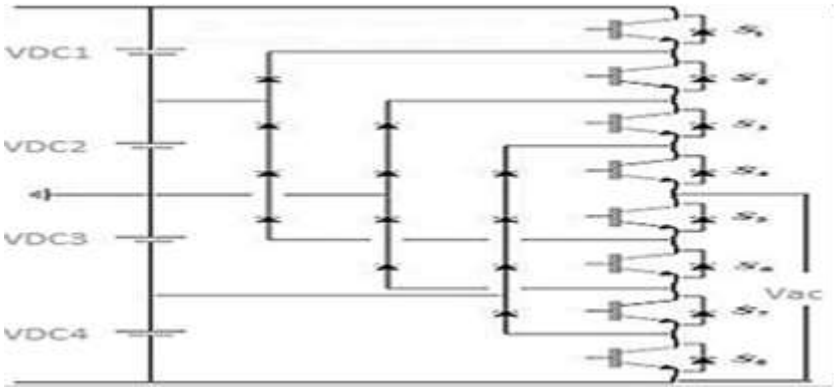


**Chart-1: Diode Clamped Multi-level Inverter**

### 2.2 Flying Capacitor MLI

The configuration topology in this inverter is rather alike to the preceding one, excluding for the variance that here capacitors are used to limit voltage instead of diodes. Flying capacitor required number of capacitors for voltage balancing, therefore, increase the cost. A m level inverter requires 2(m-1) switching devices,(m-1) input voltage source and zero operating diodes.

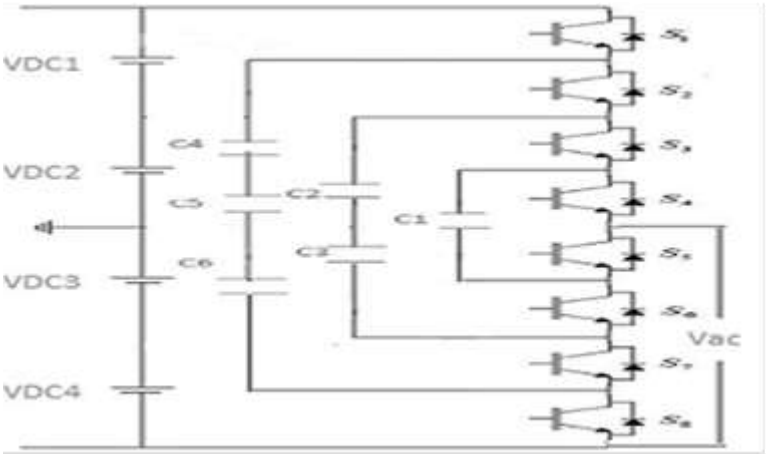


**Chart-2: Flying Capacitor Multi-level Inverter**

### 2.3 Cascade H-Bridge MLI

The idea of this kind of inverter is grounded on connections of H-bridge inverters in a cascaded manner to produce a sinusoidal output voltage. The voltage at the output is the addition of the voltages produced by all cells. Cascade H-bridge inverter (CHB-MLI) is more beneficial with regard to low dv/dt stress, less electromagnetic interference (EMI) and less total harmonic distortion (THD). Among them, CHB-MLIs are more suitable for PV arrays application as each cell of CHB-MLI operates with separate DC voltage source. Which can easily supply by individual PV arrays and all H-bridge cell will be available in a single module. A m level inverter requires 2(m-1) switching devices,(m-1)/2 input voltage source and zero operating diodes.

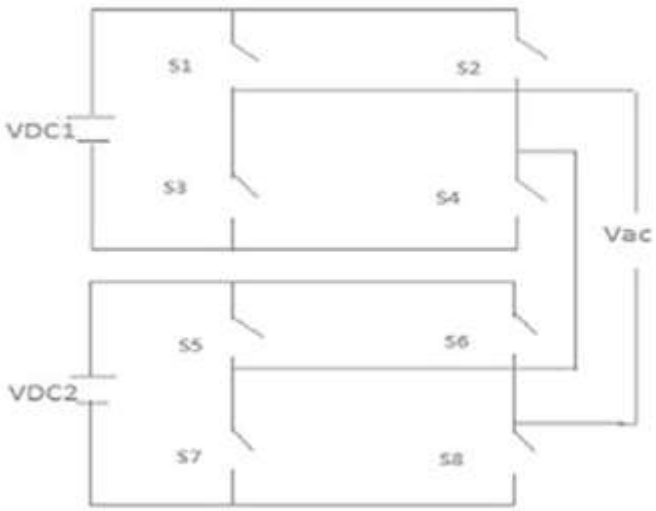


**Chart-3: Cascade H-Bridge Multi-level Inverter**

 

## 3. SIMULATION WORK

The simulation work is done in the MATLAB SIMULINK. We have made the five-level, seven-level, nine level, eleven-level and thirteen-level inverter in MATLAB by using MOSFET as a switch device. It works according to gate pulse which is given through pulse generator. We have connected the 4 MOSFETs in such a manner to make an H-bridge cell. According to the formula of cascaded H-bridge multi-level inverter, we can produce desired levels as the formula is (2m+1) where m is no. Of cells. So that we can produce desired levels just by adding the H-bridge cells according to our desired levels. Therefore, two H-bridge cell for 5 levels, three for 7 levels, four for 9 level, five for 11 levels and six for 13 levels in single phase are connected in cascaded manner.

### 3.1 Five Level H-Bridge Inverter

In five level H-bridge inverter, two H-bridge cells are connected in a cascaded manner so that it provides us five level output voltage at the output end. Two cells consist of eight MOSFETs.

We have provided an operating time period of 0.02seconds by using a pulse generator to all MOSFETs. Phase delay for MOSFETs (M1, M3) are 0.0016 And Phase delay for MOSFETs (M2, M4) are 0.0116. Phase delay for MOSFETs (M5, M7) are 0.0033 And Phase delay for MOSFETs (M6, M8) are 0.0133. The THD is 0.3192.

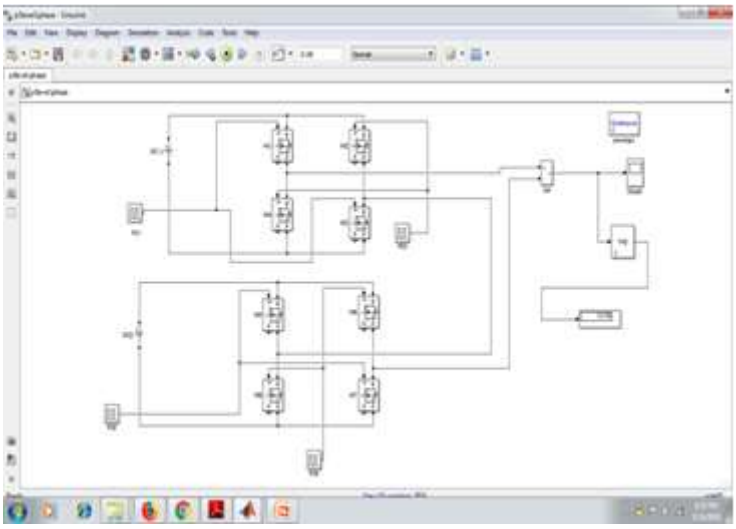

**Chart-4: Simulink diagram of single phase five-level H-bridge inverter**

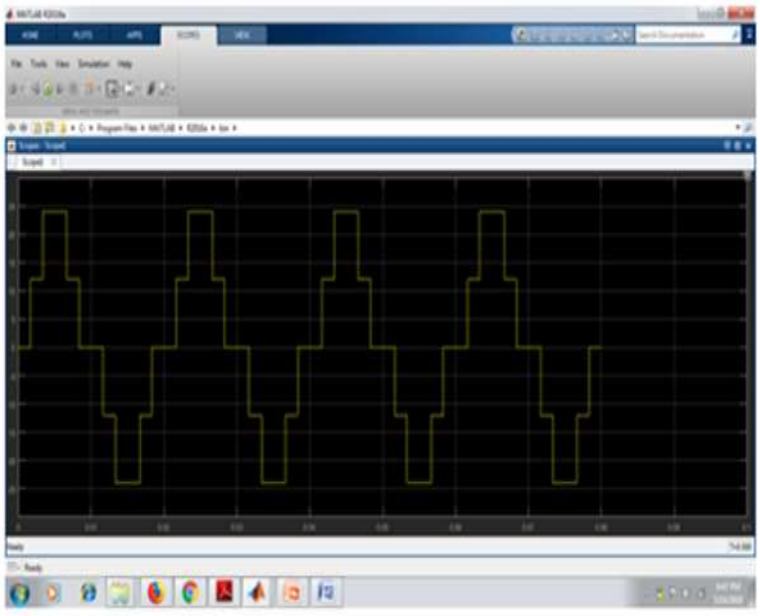

**Chart-5: Output waveform of five level H-bridge inverter**

### 3.2 Seven Level H-Bridge Inverter

In seven level H-bridge inverter, three H-bridge cells are connected in a cascaded manner so that it provides us seven level output voltage at the output end. Three cells consist of twelve MOSFETs.

We have provided an operating time period of 0.02seconds by using a pulse generator to all MOSFETs. Phase delay for MOSFETs(M1,M3) are 0.00125 And Phase delay for MOSFETs(M2,M4) are 0.01125.Phase delay for MOSFETs (M5,M7) are

 

0.0025 and Phase delay for MOSFETs(M6,M8) are 0.0125. Phase delay for MOSFETs (M9, M11) is 0.00375. Phase delay for MOSFETs (M10, M12) is 0.01375. The THD is 0.2547.

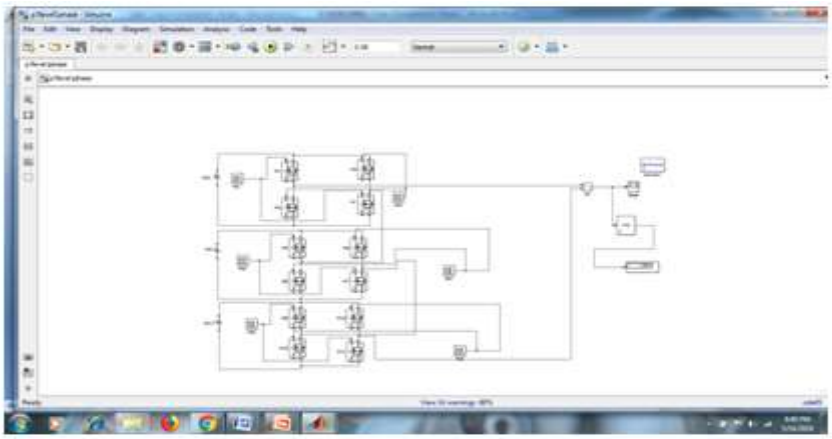

**Chart-6: Simulink diagram of single phase seven-level H-bridge inverter**

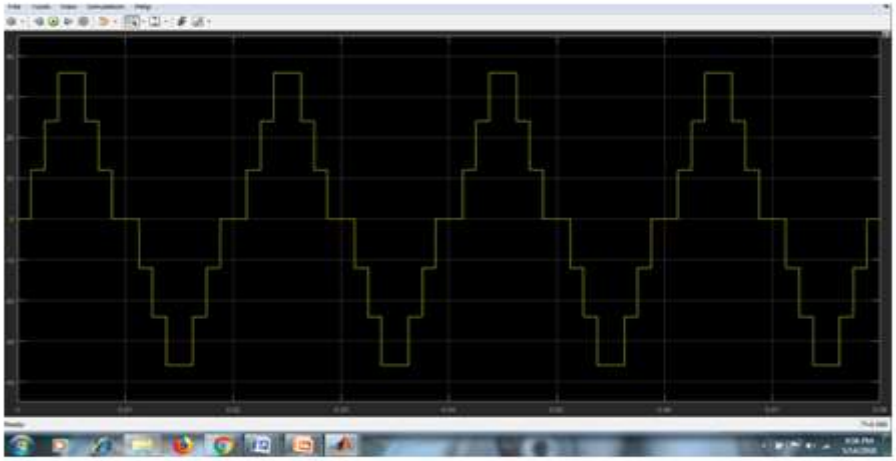

**Chart-7: Output waveform of seven level H-bridge inverter**

### 3.3 Nine Level H-Bridge Inverter

In nine level H-bridge inverter, four H-bridge cells are connected in a cascaded manner so that it provides us nine level output voltage at the output end. Four cells consist of sixteen MOSFETs.

We have provided an operating time period of 0.02seconds by using a pulse generator to all MOSFETs. Phase delay for MOSFETs(M1,M3) are 0.001 And Phase delay for MOSFETs(M2,M4) are 0.011.Phase delay for MOSFETs (M5,M7) are 0.002 and Phase delay for MOSFETs(M6,M8) are 0.012.Phase delay for MOSFETs (M9,M11) are 0.003 and Phase delay for MOSFETs (M10,M12) are 0.013. Phase delay for MOSFETs (M13, M15) are 0.004 and Phase delay for MOSFETs (M14, M16) are 0.014. The THD is 0.2205.

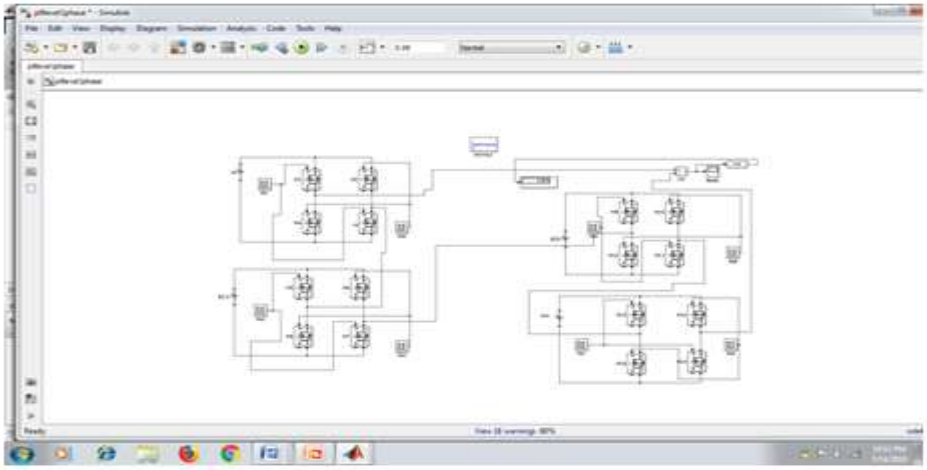

**Chart-8: Simulink diagram of single phase nine-level H-bridge inverter**

 

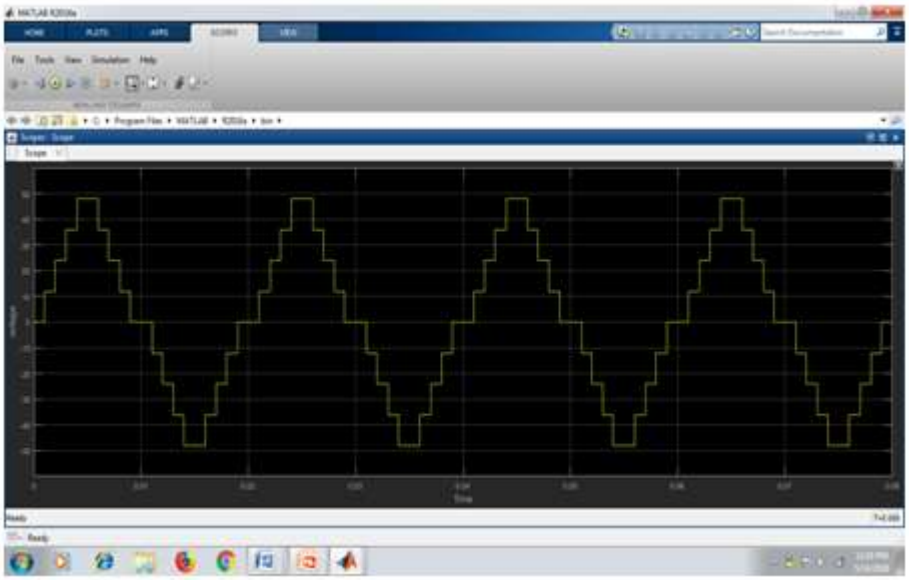

**Chart-9: Output waveform of nine-level H-bridge inverter**

### 3.4 Eleven Level H-Bridge Inverter

In eleven level H-bridge inverter, five H-bridge cells are connected in a cascaded manner so that it provides us eleven level output voltage at the output end. Five cells consist of twenty MOSFETs.

We have provided an operating time period of 0.02seconds by using a pulse generator to all MOSFETs. Phase delay for MOSFETs(M1,M3) are 0.00083 And Phase delay for MOSFETs(M2,M4) are 0.010833.Phase delay for MOSFETs (M5,M7) are 0.0016 and Phase delay for MOSFETs(M6,M8) are 0.0116 .Phase delay for MOSFETs (M9,M11) are 0.0025 and Phase delay for MOSFETs (M10,M12) are 0.0125. Phase delay for MOSFETs (M13, M15) are 0.0033 and Phase delay for MOSFETs (M14, M16) are 0.0133. Phase delay for MOSFETs (M17, M19) are 0.00416 and Phase delay for MOSFETs (M18, M20) are 0.01416. The THD is 0.1995.

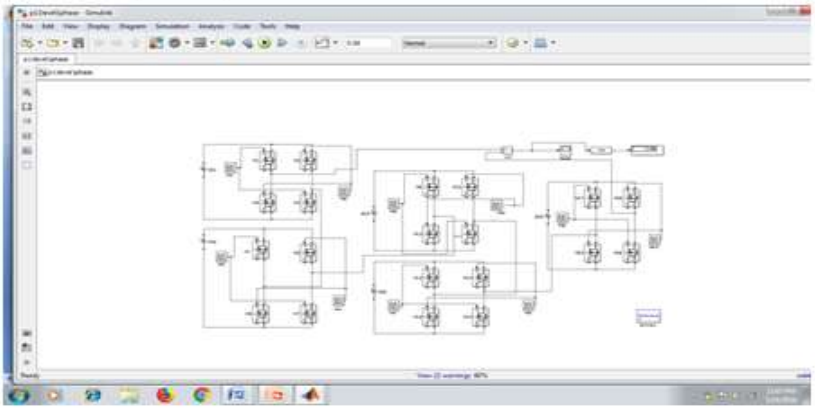

**Chart-10: Simulink diagram of single phase eleven-level H-bridge inverter**

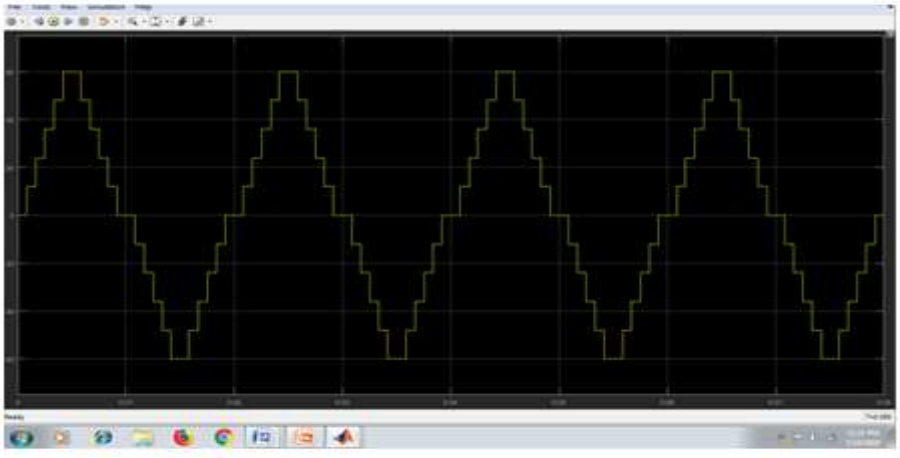

**Chart-11: Output waveform of eleven -level H-bridge inverter**

 

### 3.5 Thirteen Level H-Bridge Inverter

In Thirteen level H-bridge inverter, six H-bridge cells are connected in a cascaded manner so that it provides us eleven level output voltage at the output end. Six cells consist of twenty-four MOSFETs. We have provided an operating time period of 0.02seconds by using a pulse generator to all MOSFETs. The THD is 0.1809.

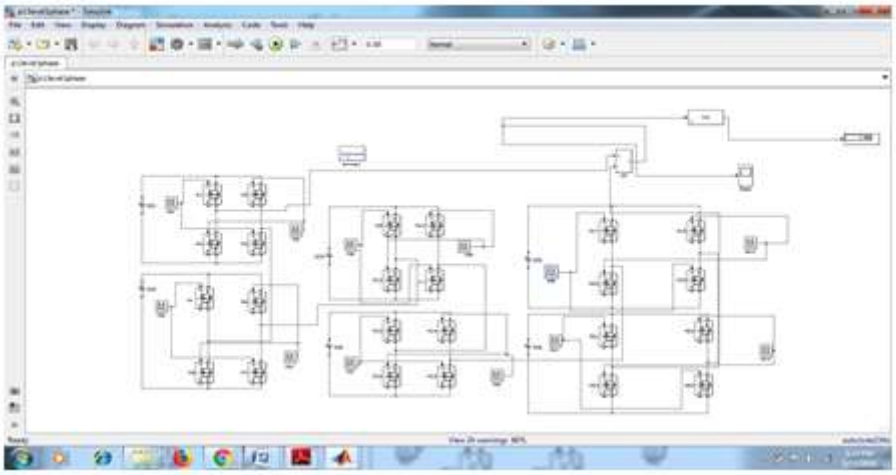

**Chart-12: Simulink diagram of single phase eleven-level H-bridge inverter**

## 4. CONCLUSION AND FUTURE SCOPE

The cascaded H-bridge multi-level inverter is better than the diode clamped multi-level inverter as well as flying capacitor multi-level inverter as it consists of less components The CHB MLI numerous advantage such as generation of high power, low dv/dt stress, less EMI, and less THD. Cascaded H-bridge MLI can also be applicable as active power filters used to compensate current and voltage harmonics using different compensation techniques which are traditional, modified and matured.

In the cascaded H-bridge multi-level inverter the output voltage becomes more smooth and sinusoidal with an increase in levels. As we have seen in the results and output waveforms of 5, 7, 9,11and 13 levels cascaded H-bridge inverters the THD has been reduced with an increase in levels.

Future perspective of the cascaded H-bridge inverter is that with an increase in the levels of the output voltage the THD reduces so that to achieve the lower THD and harmonics more than thirteen level inverter can be made viz. fifteen level, seventeen level and so on.

**Table 1**

| Serial No. | THD Percentage Comparison of Different Level Inverters | | |
|---|---|---|---|
| | *Levels* | *THD* | *THD Decreasing?* |
| 1 | 5 level inverter | 0.3192 | Yes |
| 2 | 7 level inverter | 0.2546 | Yes |
| 3 | 9 level inverter | 0.2205 | Yes |
| 4 | 11 level inverter | 0.1995 | Yes |
| 5 | 13 level inverter | 0.1809 | Yes |

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